Quantum tunneling and the principle of relativity.

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Abstract

It is shown that the results of Buttiker and Landauer on the traversal time of quantum tunneling through a potential barrier are in agreement with the principle of relativity. Also, they are consistent with the data on the life-time of nuclear particles that decay in flight.

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A tunneling of particles through a potential barrier is a quantum effect, which has been intensively studied during the last decade.. Many authors have studied the traversal time necessary the barrier to be passed, however the aim of this letter is to discuss the results obtained by Buttiker and Landauer [1]. Landauer and Martin [2] considered different points of view [3,4] on the nature of the traversal time. Due to their analysis, it was shown that the Buttiker-Landauer traversal time τ_{BL} seams to correspond quite well to the interaction time between the tunneling paticle and the barrier and can be expressed by the following equation [1]:

$$\tau_{BL} = \int_{x_1}^{x_2} m\hbar k(x)dx = \int_{x_1}^{x_2} \sqrt{m2\hbar[V_0(x) - E]}dx \tag{1}$$

Here,m and E are the mass and the energy of the particle, $V_0(x)$-is the rectangular potential barrier with turning points x_1 and x_2. The eq. (1) is valid if $V_0(x) >> E$ [1].

An attempt to estimate the value of the $V_0(x)$ for strong interacting particles has been done in [5,6]. It was shown that the value of such barrier seams to be very high, since $V_0^{si}(x)$" $10^{20}m$ [6], where m is the mass of a particle. If so, then one can assume that the barrier can be passed when $E = mv_b^2 2$. It is expected that the velocity vb is very high. However, to satisfy the principle of relativity it is necessary that always $v_b < C$, where C is the velocity of light. If $v_b -> C$, then one can transform the eq.(1) to the following equation:

$$\tau_{BL} = \Delta x C \sqrt{1 - v^2 C^2} \tag{2}$$

No doubts that the eq. (2) has fundamental significance. However, due to the lack of space we limit comments of eq. (2) giving only one clear example. Since the eq. (1) contains a relativistic multiplier, the decay in flight of particles and their larger life-time τ relative to the life-time in rest τ_0 are consistent with the principle of relativity. Assuming that $\tau_{BL} \approx \tau$ one can reach the following simple relationship:

$$\tau_0 = \Delta x C \tag{3}$$

The eq. (3) shows that the value of the width Δx of the potential barrier is equal to the "characteristic length" ($\tau_0 C$) of elementary particles. Estimated values of Δx for $\tau_0 \approx 2,2.10^{-6}$ s ($\mu^{\pm}$ - mesons); $2,6.10^{-8}s$ ($\pi^{\pm}$ - mesons) and $0,8.10^{-16}$s (π^0-meson) are as follow: $\approx\ 6,6.10^4 cm$, $\approx 7,8.10^2 cm$ and $\approx 2,4.10^{-6} cm$. These surprising results lead us to the conclusion that the decay in flight of particles could have been associated with a tunneling of particles through a potential barrier.

If the potential barrier is time-dependent, i.e. if the barrier $V(x,t) = V_0(x) + V_1(x) Cos(\omega t)$[1], then one can find some other important consequences from the results of Buttiker and Landauer's work [1].

To derive them, one should consider the results and numerical evaluations obtained in [5,6]. It was assumed that the time associated with a given particle or body depends from the relative changes of their masses, i.e. - $mdt = \Delta mm$ [5,6]. An estimation of the value of μ_n for strong interacting particles was found to be $\approx 10^{23} s^{-1}$[5]. A phenomenological approach based on the assumption that the strong interacting field "vibrates" with a frequency mn was considered in [5,6]. One could assume that the potential barrier $V(x,t)$ [1] is modulated with a frequency $\varpi \approx \mu_n$. Then the tunneling particles are expected to have energies with values of $E \pm n\hbar\varpi$ that form two "sidebands" [1]. An estimation of the change of E at $n = 1$ gives a value of $\Delta E \approx \hbar.\mu_n \approx 66 MeV$. It is important to note that both charged and neutral particles are expected to change their energies. This important result might be a physical basis for acceleration of strong interacting particles that are tunneling through a time-dependent, i.e. modulated, potential barrier.

One should note that an experimental study of the energy spectra of tunneling nuclear particles that pass through a modulated potential barrier could check all assumptions mentioned above. Also, one could obtain unique information about some of the properties of strongly interacting field.

In conclusion, one should note that it would be interesting further consideration of some of the properties of nuclear matter to be done from the point of view of quantum tunneling with dissipation [1] and a resonant interaction between particles and barriers [7].

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